Version MO/6

EGT1
ENGINEERING TRIPOS PART IB

Monday 5 June 2017 2 to 4

Paper 2

STRUCTURES

Answer not more than ***four*** *questions, which may be taken from either section.*

All questions carry the same number of marks.

The ***approximate*** *number of marks allocated to each part of a question is indicated in the right margin.*

Answers to questions in each section should be tied together and handed in separately.

Write your candidate number ***not*** *your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

10 minutes reading time is allowed for this paper.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

SECTION A

1 A weightless pin-jointed truss is shown in Fig. 1. All members have the same cross-sectional area, A, and are made of a linear elastic material with Young's modulus E. Members V and IX are of length L and do not intersect. All members are initially unstressed. A vertical load W is then applied at joint J as shown in the figure.

(a) Find the number of redundancies. [2]

(b) Use the *force method* to determine the forces in the members. Comment on the results and suggest a simple alternative method for determining the forces in the truss. [18]

(c) Find the displacement of joint J. [5]

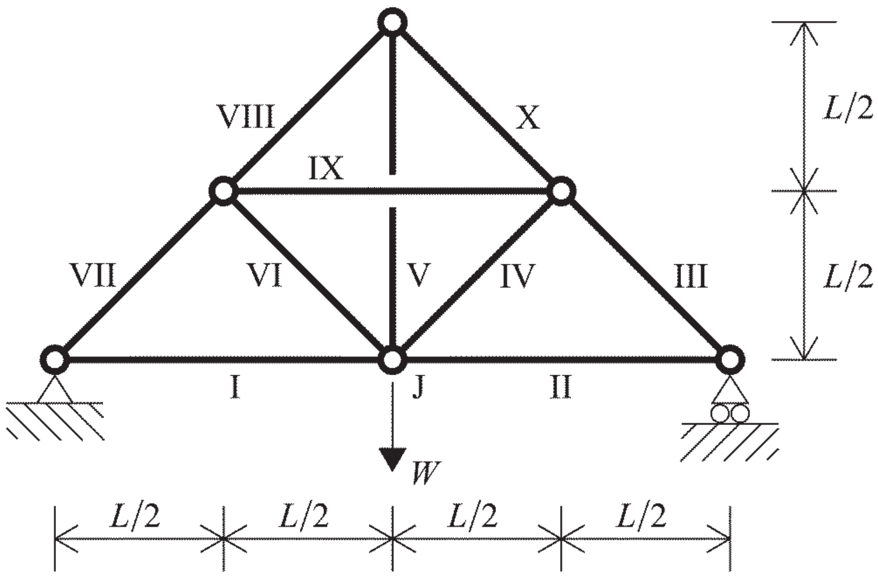
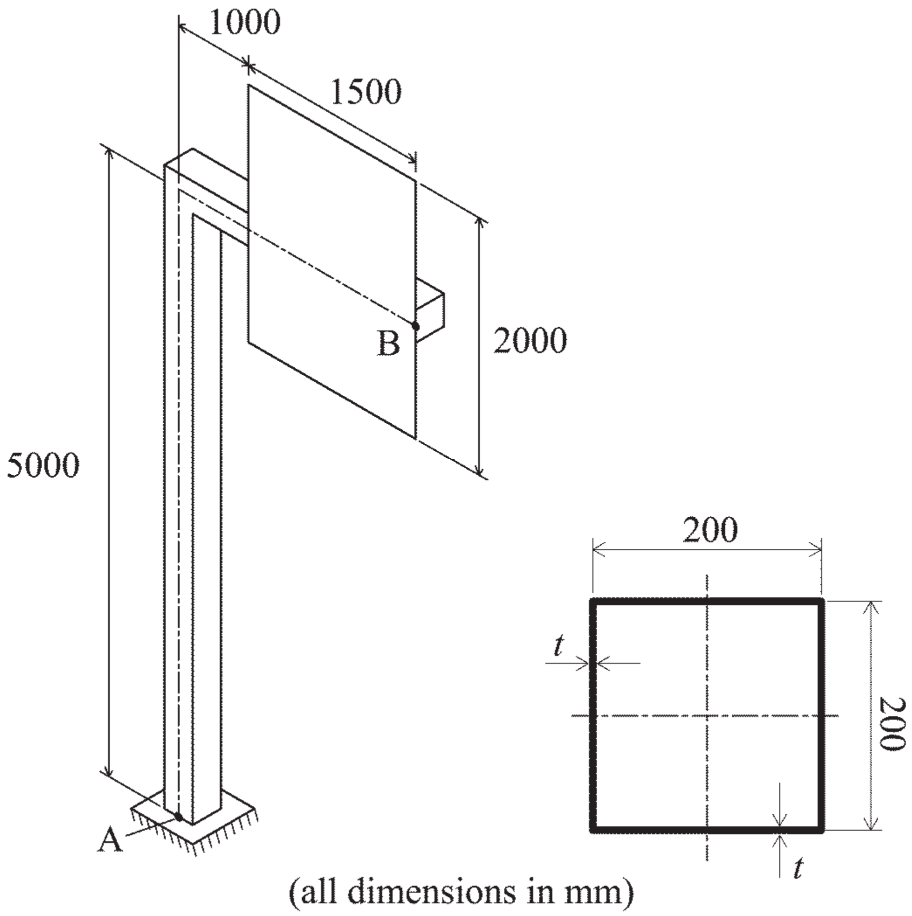


Fig. 1

2 The road sign shown in Fig. 2(a) is supported by a structure made from a thin-walled hollow steel section. The cross-sectional dimensions of the hollow section are shown in Fig. 2(b). The steel has a Young's modulus of 210 GPa, a Poisson's ratio of 0.3 and a yield strength of 460 MPa. The 2 m by 1.5 m sign is subjected to a constant uniform wind pressure of 2 kPa acting normal to the sign. The self-weight of the sign and structure are negligible. The thickness of the sign may be ignored.

(a) Determine the deflection at point B in terms of the bending and torsional rigidities of the hollow section and calculate the minimum wall thickness, *t*, required to limit the deflection at this point to 0.15 m. [12]

(b) Calculate the torque, shear force and bending moment at the base of the hollow section. Use the von Mises yield criterion and a wall thickness of 10 mm to find the magnitude of wind pressure that will cause initial yield at point A. [13]



(a) (b)

Fig. 2

3 (a) The simply supported beam in Fig. 3(a) is subjected to two vertical concentrated loads of magnitude W at distances αL from each end. Assuming that the response of the beam is linear elastic and that its flexural rigidity is EI, show that the rotation at B is $W\alpha L^2(1-\alpha)\,/\,2EI$. [5]

(b) The weightless right-angled portal frame shown in Fig. 3(b) is initially stress-free and all members have a flexural rigidity EI. Two concentrated loads, W, are applied normal to member AB, as shown. Assuming that the frame remains elastic, and that axial flexibility and shear deformation may be neglected:

(i) calculate the support reactions at the simply supported end A and the fixed end C in terms of W, α and L; [10]

(ii) determine the positions and magnitudes of the maximum positive and negative moments in the frame and, for a value α = 0.25, sketch the bending moment diagram indicating salient values. [10]

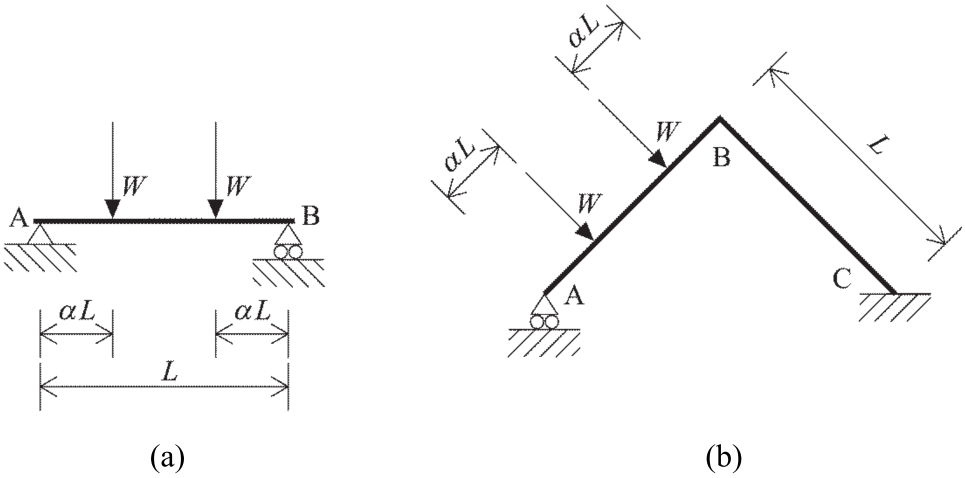


Fig. 3

SECTION B

4 Figure 4(a) shows a propped steel cantilever made of the cross-section shown in Fig. 4(b). A load of total magnitude W is applied over half of the span as shown and the self-weight of the cantilever is negligible. The steel has a yield stress of 355 MPa and a Young's modulus of 210 GPa.

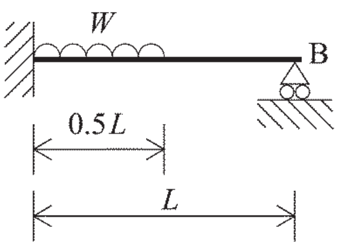
(a) Calculate the elastic and the plastic section moduli of the cross-section about its major axis. [4]

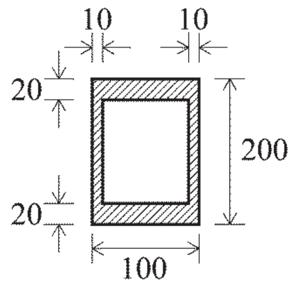
(b) Perform an elastic analysis to calculate the magnitude of load W and the mid-span deflection when first yield occurs at the clamped support. [10]

(c) Perform a lower bound analysis to calculate the load W when the full plastic moment capacity is reached at the clamped support. [4]

(d) As the load W increases the first plastic hinge, which forms at the clamped support, is followed by a second plastic hinge in the unloaded half of the span. Perform an upper bound analysis to determine value W at collapse. [3]

(e) Sketch the load *vs* mid-span deflection plot for the propped cantilever, showing salient values from the solutions to parts (b), (c) and (d). Estimate the mid-span deflection when the full plastic moment capacity is reached at the clamped support. [4]





(all dimensions in mm)

(a) (b)

Fig. 4

5 The inclined portal frame shown in Fig.5 is composed of two columns with fully plastic moment M_p and an inclined beam with fully plastic moment $2M_p$. The frame is subjected to a horizontal uniformly distributed load of total magnitude H and a vertical point load V applied at mid-span.

(a) Sketch five feasible collapse mechanisms, showing clearly the locations of the plastic hinges. [5]

(b) Perform an upper bound analysis to determine the collapse loading conditions associated with each of the mechanisms identified in part (a) and plot the results on a single interaction diagram. [15]

(c) The designer wishes to reduce the fully plastic moment of the inclined beam from $2M_p$ to M_p without affecting the collapse load of the portal frame. Modify your interaction diagram from part (b) to assess this option. [5]

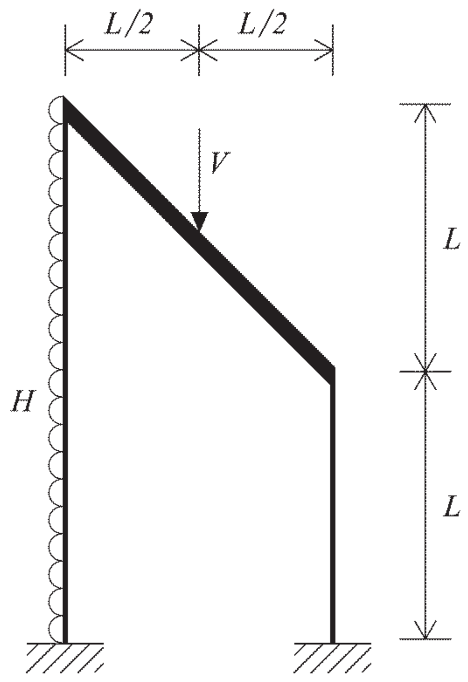


Fig. 5

6 (a) What are yield lines and how would you ensure that a proposed yield line pattern satisfies compatibility requirements? [3]

(b) A ductile isotropic plate is supported on four interior points as shown in Fig. 6(a). The plate has a fully plastic moment capacity of m per unit length. The plate has negligible self-weight and is subjected to a uniformly distributed load of total magnitude W acting normal to the plate. Two collapse mechanisms are shown in Fig. 6(b) and Fig. 6(c).

(i) Sketch two further simple collapse mechanisms for the plate and indicate the axes of rotation and any variable parameters to be used in a yield line analysis. [4]

(ii) By considering the two collapse mechanisms shown in Fig. 6(b) and Fig. 6(c), find the critical value of W when $0.5 \leq \alpha \leq 1.0$. Plot your results on a W *vs* α graph and identify the optimal value of α. [10]

(iii) For $\alpha = 1.0$ analyse the collapse mechanisms you have proposed in part (b)(i). Hence show that the critical value of W cannot be improved compared to the results found in part (b)(ii). [8]

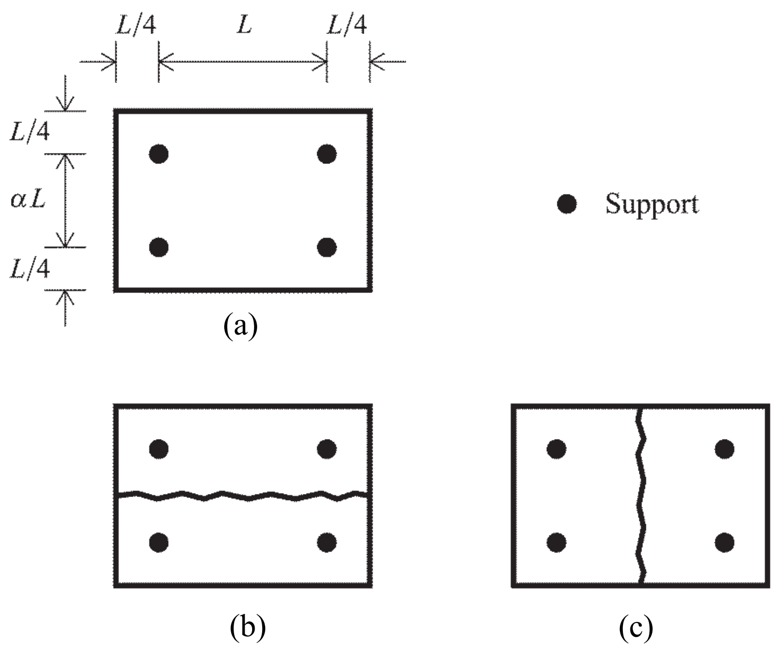


Fig. 6

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